Does Previous Extracorporeal Shock Wave Lithotripsy Affect the Performance and Outcome of Percutaneous Nephrolithotomy?

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Purpose: ESWL® and percutaneous nephrolithotomy are the primary treatment modalities for kidney stones. Furthermore, percutaneous nephrolithotomy is first line treatment when ESWL fails. We assessed how previous ESWL affects the performance and outcome of percutaneous nephrolithotomy.

Materials and Methods: A total of 1,008 patients underwent percutaneous nephrolithotomy between 2002 and 2007, of whom 230 (22.8%) had a recent history of failed ESWL. Patient characteristics, operative findings, success and complication rates in patients with and without a history of ESWL were analyzed and compared.

Results: In the post-ESWL group mean stone size was significantly lower and the mean ± SD interval between the last ESWL session and percutaneous nephrolithotomy was 3.4 ± 2.1 months (range 1 to 12). Mean operative time and fluoroscopic screening time were similar in the 2 groups ($p > 0.05$). However, mean operative time per cm^2 stone and fluoroscopic screening time per cm^2 stone were significantly prolonged in the post-ESWL group ($p < 0.05$). At a mean followup of 5.6 ± 1.2 months (range 3 to 6) an overall success rate of 89% was achieved. Success and complication rates were comparable in the 2 groups.

Conclusions: Although similar success and complication rates were achieved with percutaneous nephrolithotomy after failed ESWL, percutaneous nephrolithotomy is usually more difficult with prolonged operative time and fluoroscopic screening time per cm^2 stone due to the tissue effects of ESWL and scattered stone fragments in the pelvicaliceal system.

Key Words: kidney; kidney calculi; nephrostomy, percutaneous; lithotripsy; complications

Abbreviations and Acronyms

AUA = American Urological Association

CIRF = clinically insignificant residual fragments

EAU = European Association of Urology

FST = fluoroscopic screening time

PNL = percutaneous nephrolithotomy

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PERHAPS in no other field of surgery has the treatment of a condition changed so dramatically and in such a short period as in active treatment for nephrolithiasis.[1] The last 25 years have seen a remarkable shift from open procedures such as nephrolithotomy to endourological interventions, including ESWL, ureteroscopy, retrograde intrarenal surgery and PNL.[1]

Since its first presentation in Germany in the early 1980s, ESWL has revolutionized treatment for urinary lithiasis.[2,3] ESWL has gained rapid acceptance worldwide because of its ease of use, noninvasive nature, high efficacy for treating kidney and ureteral stones, and the wide availability of lithotriptors. ESWL now stands as the preferred treatment for kidney stones in most cases today.[3]

Although it was at first believed to be harmless to renal and other tissues, it soon became evident that

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ESWL causes some degree of renal injury and functional impairment in most if not in all patients depending on the number, frequency and energy (kV) of shock waves as well as kidney disease, solitary kidney and kidney size.[4] On the other hand, PNL is still first line surgical treatment for renal calculi. Especially for larger stones and staghorn calculi PNL remains the first treatment modality recommended by the EAU Guidelines on Urolithiasis[5] and AUA guidelines on staghorn calculi.[6] Furthermore, stones resistant to ESWL can also be managed by PNL.

However, to our knowledge there are no data in the literature on the impact of extracorporeal shock waves on the success of PNL for managing ESWL resistant stones. We evaluated the effects of previous unsuccessful ESWL treatment on the performance and outcome of PNL.

MATERIALS AND METHODS

A total of 1,008 consecutive PNL procedures for renal calculi were performed at our institution from September 2002 to June 2007 under the supervision of a single surgeon (AT). All data were maintained prospectively using Microsoft® Excel® and analyzed retrospectively. Of these 1,008 patients 230 (22.8%) with a history of unsuccessful ESWL on the same side comprised group 1. The remaining 778 patients (77.2%) without a history of ESWL comprised group 2.

Radiological investigation consisted of excretory urography, and/or urinary ultrasound and noncontrast spiral tomography in select cases. Stone size was assessed as the surface area and calculated according to EAU guidelines.[5] A complete blood count along with the basic metabolic tests (blood urea nitrogen, electrolytes, serum creatinine, liver function tests, prothrombin time and partial thromboplastin time) were done in each patient before intervention. Urine culture was also performed 1 week before surgery and any condition was treated promptly if needed.

Each patient underwent PNL as previously described in detail, beginning with cystoscopy and insertion of a ureteral catheter to enable contrast material delineation of the renal collecting system when necessary.[7] Percutaneous access was achieved at a single setting in the operating room with C arm fluoroscopy performed by the attending urologist. The tract was dilated with a high pressure NephroMax™ balloon dilator using a Leveen™ inflator and a 30Fr Amplatz sheath placed over the inflated balloon dilator. Nephroscopy was performed with a rigid 26Fr nephroscope. Stone burden fragmentation was accomplished using a pneumatic Vibrolith lithotriptor (Elmed, Ankara, Turkey) or an ultrasonic lithotriptor (Swiss LithoClast® Master) depending on availability. Forceps was used to remove stone fragments. Additional tracts were created when indicated at the same session. A 14Fr nephrostomy tube was placed in the renal pelvis or the involved calix at the conclusion of each case.

Antibiotic prophylaxis was maintained by quinolones. The first dose (200 mg ciprofloxacin) was administered intravenously when anesthesia was initiated and the second dose was given 12 hours later. Patients then received oral ciprofloxacin until the nephrostomy tube was removed.

Plain x-ray of the kidneys, ureters and bladder was done on postoperative day 1. In cases rendered stone-free and in those with no clinically significant residual fragments the nephrostomy tube was removed on postoperative day 2 after antegrade nephrostogram showed ureteral drainage down to the bladder. A Double-J® catheter was considered when urine drainage from the tract persisted more than 24 hours after nephrostomy tube removal. Repeat PNL, ureteroscopy and ESWL were considered as accessory treatment alternatives when indicated.

All cases were evaluated with excretory urography and/or spiral computerized tomography in select cases 3 to 6 months postoperatively. Results were classified as stone-free, CIRFs and unsuccessful (residual stones) in each group separately. CIRFs were considered to be 4 mm or less, nonobstructing, noninfectious and asymptomatic residual fragments.[7,8] PNL was considered successful when the patient was stone-free or had CIRFs.[7,8]

Operative findings, including operative time, FST, success rate, need for auxiliary treatments and complications observed, were documented in detail and compared in groups 1 and 2. Furthermore, operative time per stone cm^2 and FST per stone cm^2 were calculated and the mean ratios were compared.

Data are expressed as the mean ± SD. Statistical analysis was performed using the chi-square and Student t tests with $p < 0.05$ considered significant.

RESULTS

Table 1 lists patient demographics and stone characteristics. Patient mean age and gender distribution were similar in the 2 groups but mean stone size was significantly smaller in group 1 (table 1). In group 1 the mean interval between the last ESWL session and PNL was 3.5 ± 2.1 months (range 1 to 12). A history of open surgery for kidney stone dis-

Table 1. *Characteristics of patients treated with PNL and stone characteristics*

	Overall	Group 1	Group 2	p Value
No. pts		230	778	
Mean age ± SD (range)	43.1 ± 14.7 (8–81)	44.0 ± 15.1 (13–80)	42.8 ± 14.6 years (8–81)	>0.05
No. men/women	576/432	129/101	447/331	>0.05
Mean stone size ± SD (cm^2)	8.1 ± 5.3 (1.5–30)	6.8 ± 5.3 (1.5–25)	8.3 ± 5.3 (1.5–30)	<0.05
No. staghorn stones (%)	122 (12.1)	20 (8.6)	102 (13.1)	<0.05

ease was present in 55 (24%) and 159 patients (20.4%) in groups 1 and 2, respectively ($p > 0.05$).

Table 2 lists operative findings. Mean operative, FST and hospitalization times were similar in the 2 groups ($p > 0.05$). However, mean operative time per cm^2 stone was 8.6 and 7.3 minutes per cm^2 in groups 1 and 2, respectively (table 3). This difference was statistically significant ($p < 0.05$). Similarly FST per cm^2 stone was 1.65 minutes per cm^2 in group 1 and 1.16 minute per cm^2 in group 2 (table 3), which was also statistically significant ($p < 0.05$). Multiple percutaneous access was indicated in 44 (18.9%) and 131 patients (16.8%) in groups 1 and 2, retrospectively ($p > 0.05$).

At a mean followup of 5.6 ± 1.2 months (range 3 to 6) an overall 89.3% success rate was achieved (table 2). Complete stone clearance was accomplished in 80% and 79.1% of patients in groups 1 and 2, respectively ($p > 0.05$). Auxiliary treatment alternatives, including repeat PNL in 45 patients (9 and 36 in groups 1 and 2) and postoperative ESWL in 43 (8 and 35, respectively), were performed in 94 (9.3%) (table 2).

The overall complication rate was similar in groups 1 and 2 (61 patients or 26.5% and 224 or 28.8%, respectively). Hemorrhage necessitating blood transfusion was observed in 21 (9.1%) and 72 patients (9.2%) in groups 1 and 2, respectively ($p > 0.05$). Ureteral laceration, which was managed conservatively by prolonged Double-J stent placement, was noted in 2 patients (0.8%) in group 1 and in 12 (1.5%) in group 2. Hydrohemopneumothorax was observed in 3 patients in group 2. Perirenal hematoma developed after PNL in 3 group 2 patients, which was treated conservatively in 2 and with nephrectomy in 1. Selective arterial embolization was performed in 2 patients due to prolonged hematuria related to an arteriovenous fistula. One patient died of septic shock 1 week after PNL.

Table 3. *Corrected operative time and FST ($p < 0.05$)*

	Mean Mins/Cm² Stone Time (range)	
	Group 1	Group 2
Operative time	8.60 (5–10)	7.31 (6–10)
FST	1.65 (0.5–2.2)	1.16 (0.4–2.1)

DISCUSSION

The modern trend has become active treatment for urinary stone disease with advancements in endourological modalities.[9] With this trend mean size of the treated stone has decreased. EAU guidelines recommend active treatment for stones greater than 7 mm.[5] ESWL is the first line treatment modality for stones smaller than 20 mm and PNL is generally done for stones greater than 20 mm.[5] Furthermore, PNL can be performed as first line treatment when ESWL fails. EAU guidelines recommend PNL if 3 to 5 sessions of ESWL treatment fail.[5] According to AUA guidelines PNL should be the first treatment in most patients with staghorn calculi and, if combination therapy is performed, percutaneous nephroscopy should be the last procedure in most patients.[6] PNL is also used for stones fragmented with ESWL but is not suitable for spontaneous passage.

Despite guidelines on managing renal stones[5,6] the widespread use of ESWL at nonacademic centers does not always match these rules. Therefore, mean stone size in group 1, consisting of patients referred to us after unsuccessful ESWL, was 6.8 cm^2. Stone size was larger than 2 cm in 76.9% of patients (177) and 8.3% had staghorn stones. Furthermore, although it was at first believed to be harmless to renal and other tissues, it soon became evident that ESWL causes some degree of renal injury and functional impairment in most if not all patients. Advances in shock wave technology have led to the production of systems with lower complication rates and higher patient acceptance. However, case reports and experimental studies of

Table 2. *Preoperative and operative findings ($p > 0.05$)*

	Overall	Group 1	Group 2
No. pts		230	778
Mean mg/dl preop serum creatinine ± SD (range)	1.04 ± 0.4 (0.4–3.6)	1.06 ± 0.4 (0.5–3.4)	0.99 ± 0.4 (0.4–3.6)
Mean mins operative time ± SD (range)	60.2 ± 19.4 (15–180)	58.5 ± 19.1 (15–125)	60.7 ± 19.5 (15–180)
Mean mins FST ± SD (range)	10.0 ± 8.4 (1–64)	11.2 ± 7.9 (1–19)	9.7 ± 8.5 (1–64)
Mean days hospitalization (range)	2.8 (1–19)	2.8 (1–19)	2.7 (1–15)
Mean days nephrostomy removal (range)	2.8 (1–30)	2.8 (1–14)	2.8 (1–30)
No. success (%)	901 (89.37)	205 (89.13)	696 (89.45)
No. stone free (%)	800 (79.36)	184 (80)	616 (79.17)
No. CIRFs (%)	101 (10.01)	21 (9.13)	80 (10.28)
No. unsuccessful (%)	106 (10.51)	24 (10.43)	82 (10.53)
No. auxiliary treatment (%):			
ESWL	43 (4.26)	8 (3.47)	35 (4.49)
PNL	45 (4.46)	9 (3.91)	36 (4.62)

ESWL complications are still being published in increasing numbers.

Factors predisposing to ESWL failure are stone composition, size, location and number as well as renal morphology, and shock wave rate and energy.[10,11] The fragmentation rate of cystine and calcium oxalate monohydrate stones is lower.[12] The ESWL success rate decreases as stone size increases. In 1984 Chaussy et al reported a 91% stone-free rate for stones less than 2 cm^2 with a stone-free rate of 50% to 70% for 2 to 3 cm stones and a rate that further decreased for staghorn stones.[13] The success rate of ESWL is also lower for lower pole calculi than for stones at other locations.[14] Lingeman et al reported a stone-free rate of 29% in patients with 11 to 20 mm lower pole calculi and 20% in those with calculi greater than 20 mm.[14]

Complications observed after ESWL can be divided into subgroups, including complications related to stone fragments, infectious and renal complications, hypertension and cardiovascular complications during ESWL.[3] Incomplete fragmentation, residual stone fragments, steinstrasse and obstruction are among the problems that urologists confront when ESWL fails to completely fragment the treated stone.[3]

The possible renal effects of ESWL can be subdivided into acute and chronic effects. Acute effects include damage to the vascular endothelium, renal tubule and interstitium, increased excretion of metabolites indicating renal damage, hematoma and a decreased glomerular filtration rate.[3] Chronic effects are perirenal fibrosis and loss of renal function.[3] We do not have enough data on the functional effects of previous ESWL in our series. However, when we compared mean preoperative creatinine in groups 1 and 2, no statistically significant difference was noted (table 2), although no detailed functional assessment was performed before ESWL or PNL. On the other hand, studies in animals and humans have revealed that the decrease in the glomerular filtration rate and renal plasma flow soon after ESWL resolves within days to a couple of months.[15,16] This may also explain why we did not note any functional difference between groups 1 and 2 since we waited a mean of 3.5 $\pm$ 2.1 months (range 1 to 12) before performing PNL.

Although there are many studies and reviews of the tissue effects and complications of ESWL, to our knowledge there are no publications about the clinical significance of these tissue effects and no comment in the literature about what the intrarenal collection system looks like during PNL after ESWL treatment. Because some patients are resistant to ESWL and there is always the risk of stone recurrence, we assessed how ESWL therapy alters the results of PNL.

Our current experience shows that patients undergoing PNL after unsuccessful ESWL may have some nonspecific and subjective nephroscopy findings, such as fragile tissues, bruised calices and white membranes in the pelvicaliceal spaces. Furthermore, these patients have stone fragments scattered within the kidney calices and they may need additional percutaneous access. All of these factors can be considered potential risk factors that complicate PNL. In our study the number of patients undergoing multiple percutaneous access was similar in groups 1 and 2 despite a smaller mean stone size in the failed ESWL group. Furthermore, mean operative time, FST and the complication rate were similar in the 2 groups. On the other hand, when we compared mean operative time per stone size and FST per stone size in the 2 groups, we clearly noted that each rate was significantly augmented in the post-ESWL group, indicating that previous ESWL prolonged PNL operative time and FST.

Although the mean difference in operative time per cm^2 stone of 1.3 minutes per cm^2 seems brief, this difference is statistically significant. Furthermore, this difference supports our clinical experience with difficulties in having to chase multiple fragments during PNL after ESWL. Therefore, AUA and EAU guidelines must be followed strictly when suggesting treatment options to patients.

Despite high success rates the major concerns with percutaneous renal surgery involve serious complications, such as blood loss, adjacent organ injury and life threatening infection.[17] When stratifying PNL complications as major and minor, Lee et al reported major complications (death, bleeding necessitating intervention, significant infection, urinary tract injury and injury to adjacent organs) in 6% of patients and minor complications (postoperative fever, bleeding necessitating transfusion, extravasation, tube dislodgment, pneumonia, prolonged urine drainage from the flank, etc) in greater than 50% undergoing PNL.[18]

In a recent study we reported complications of PNL in 811 patients.[17] Postoperatively we noted fever in 33 patients (4%), blood transfusion requirement in 89 (10.9%), urinary tract infection in 7 (0.8%), Double-J stent placement for urine leakage greater than 24 hours in duration in 38 (4.6%), arteriovenous fistula in 2 (0.2%), neighboring organ injury in 3 (0.3%) and urosepsis in 3 (0.3%).

To our knowledge this study is the first to describe the effects of previous ESWL on the perioperative complications and outcomes of PNL. However, this study has several limitations. Data were analyzed retrospectively and not cross matched. Therefore, further prospective studies are needed. Success and complication rates in patients undergoing PNL after failed ESWL were similar to the rates in those without such an ESWL history. Another limitation of the study was that all patients were not assessed postoperatively by computerized tomography but were generally followed by urography, which overestimates complete stone clearance. In our series the complication rate observed during PNL after failed ESWL was similar to the rate in counterparts despite prolonged operative time and FST adjusted to stone size. This controversy can be explained by the facts that PNL complications are usually related to the vascular and caliceal anatomy of the kidney,[19] and previous surgery as well as failed ESWL are not independent risk factors for complications.[20]

CONCLUSIONS

PNL can be safely performed after ESWL failure and similar success rates can be achieved. However, the tissue effects of ESWL as well as the fragmentation and scattering of stones after ESWL usually makes the procedure more difficult, and prolongs the operation and FST per stone size, which have a negative impact on operation costs. Therefore, patients must be informed that PNL after failed ESWL is a successful but more difficult procedure.

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